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TIDAL STREAM INDUSTRY UPDATE

States of Jersey

States of Jersey

Quality Management

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Table of Contents

Executive Summary

Jersey's Tidal Stream Energy Resource

There is a reasonable resource of tidal stream energy off the coast of Jersey. As reported in 2010, 360GWh of tidal stream energy passes through the North-East site annually, however, only around 20% of this energy is available for extraction and conversion into electricity. Jersey's electricity demand is 53,475 tonnes of oil equivalent[1], equating to approximately 620GWh. A 30MW tidal stream energy farm would produce around 36 GWh/year, representing less than 6% of Jersey's electricity demand and 2% of Jersey's overall energy demand.

Tidal Stream Costs

Since ITPEnergised's original study into the feasibility of tidal stream energy for the States of Jersey (2010) the tidal industry has not progressed as expected; although there are a number of well-developed tidal stream technologies that are suitable for extracting tidal stream energy, their costs remain high. It is estimated that to harness Jersey's tidal stream resource, a 30MW farm of fixed bed turbines would have a levelised cost of energy £490 per MWh. The predicted costs are based on more evidence than was available in 2010 and are higher due to the slow development of the industry and costs not reducing as anticipated. The costs of tidal stream energy in Jersey compares unfavourably to the cost of new offshore wind and nuclear in the UK which are currently at £57.5 MWh[2] and £92.50/MWh[3] (2012 prices) respectively.

Support and Subsidies

Considering the high cost of energy predicted here, it is unlikely that project developers would look to exploit Jersey's tidal streams in the near future without incentives in the way of either revenue support, capital cost support or a streamlined development process and political desire put in place by the States of Jersey. Currently, no support or subsidies are available to Jersey from external sources (France or the UK) and so, tidal stream is not economically viable. Considering the energy resource, the site may become commercially viable as the industry progresses, however, it doesn't offer a solution in of itself to Jersey's energy needs, nor is tidal stream energy able to compete with the cost of other low carbon power production methods in Jersey.

Technology

The leading tidal technologies are mainly axial flow turbines and are either fixed to the seabed or float in the water column or at the sea surface. The industry has recently started to move on from testing commercial demonstrators to developing its first tidal stream farms, with MeyGen, in the Pentland Firth, Scotland, being the prime example of a farm development. Notwithstanding this progress, reliability issues and high capital costs are still a feature of the industry, highlighting that the industry is still in its infancy.

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[1] Jersey Energy Trends 2015, States of Jersey

[2] For offshore wind projects being commissioned in 2022/23 - Contracts for Difference Second round allocation, UK Government

[3] www.gov.uk/government/collections/hinkley-point-c

1 Introduction

1.1 Background

In 2009 IT Power was commissioned by the States of Jersey to investigate the feasibility of harnessing the tidal stream energy off the coast of Jersey. The study was completed in 2010 and its findings were outlined in a report entitled, "Tidal Stream Energy Feasibility Study for the States of Jersey". This report revisits the work previously carried out by IT Power, and provides the States of Jersey with an industry progress report, and an update on cost of energy estimations for harnessing the tidal stream energy off the North-East coast of Jersey.

In 2016, ITPEnergised (ITPE) was formed through the environmental consultancy, Energised Environments Limited, acquiring IT Power Consulting Limited, with the merged businesses being re-branded as ITPEnergised. ITPE is an ISO 9001 certified company and Quality Assurance processes underpin all of our work. This covers project management, document approval, client satisfaction, and data storage and protection. All reports and calculation spreadsheets are quality checked according to ITPE's QA policy before being issued.

In 2010, IT Power conducted a resource assessment for the channel between Jersey and Les Écréhou off the island's north-east coast. This assessment was verified with a subsequent site survey. It was concluded that there is a considerable tidal stream resource in the North East of Jersey, which could be of commercial interest. It was concluded that the route to maximising the value of this resource for the States of Jersey would be to remove the uncertainties around it in terms of generic environmental issues, consenting and leasing requirements. On the understanding that the technology was still in its infancy, there was no early imperative for the States of Jersey to secure the power that can be derived from the resource. This allowed the States of Jersey to see how the industry developed before progressing with their own tidal energy projects.

Although the environmental considerations are not revisited in the update represented here, the progress of the industry since 2010 is outlined and the economics of a potential 30MW farm to harness the tidal stream energy are reassessed. In addition, an update of the support currently offered by the UK Government to the tidal industry is presented.

2 Industry Update

2.1 Development History

The first tidal stream turbines appeared in the UK in the 1990s and early 2000s. These were small scale, pre-commercial, prototype devices and were not grid connected. By the mid-2000s larger grid connected devices were deployed. Development has continued and in late 2016 the first full scale devices intended for commercial operation were deployed. Figure 1 shows the deployment history of tidal stream turbines in the UK up until 2016.

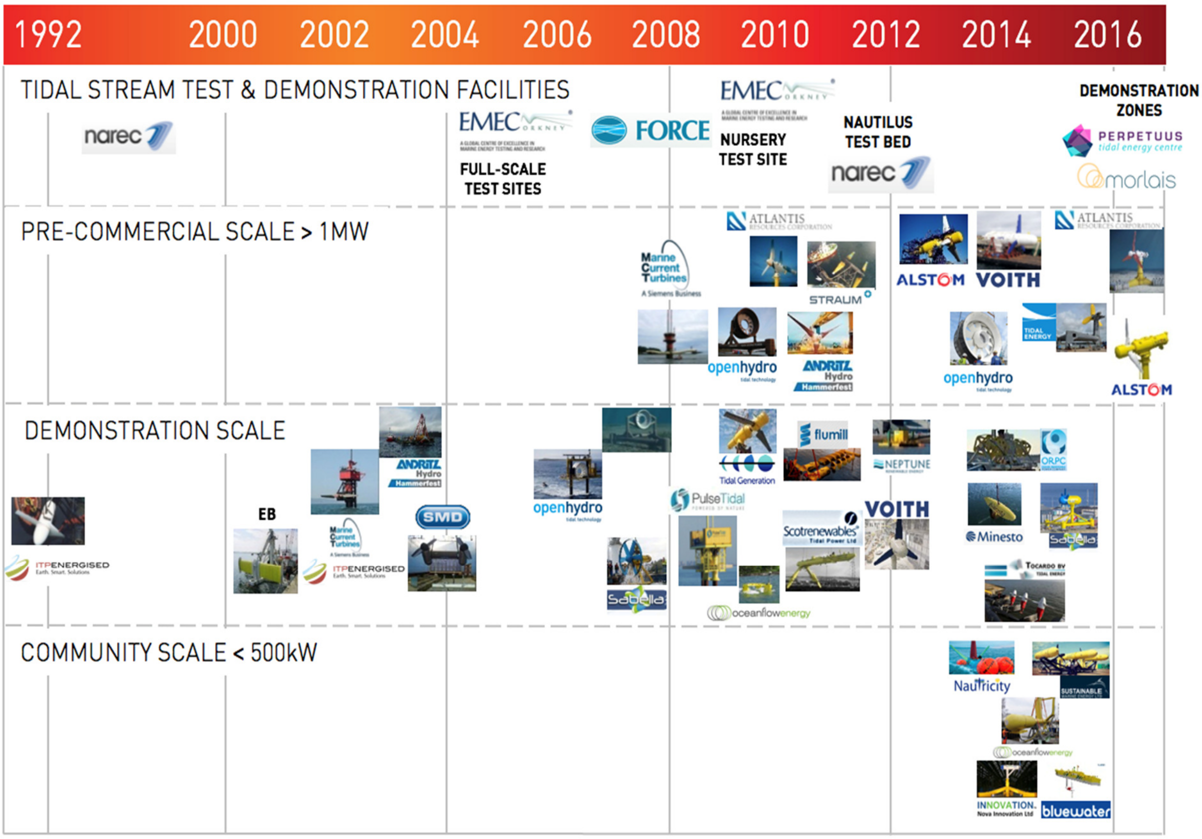


Figure 1, The main deployments of tidal stream turbines in Europe until 2016

2.2 Concept Classification

Extracting the energy available in a flowing fluid can be done in number of ways. Using a reaction turbine to convert the hydrokinetic power into mechanical power is the most common option. The different types of tidal stream turbine can be placed into one of the following categories:

1. **Axial Turbines**: These are turbines in which the rotational axis of the rotor is parallel to the incoming flow. Turbines of this type will usually employ lift type blades that are shaped as aerofoils and rotate relative to the flow. Axial flow turbines are a common choice amongst developers of tidal energy converters and are similar in concept and design to modern day wind turbines**.**

2. **Vertical Axis Turbines:** These are turbines where the rotational axis of the rotor is vertical to the water surface and perpendicular to the incoming flow. Turbines of this type employ either lift or drag type blades, with some designs using a combination of both. Savonius rotors are

drag based and rely on being pushed by the flow, usually at a speed slower than the free stream velocity. The rotor generates high torque at low speeds, making it desirable for applications such as water pumping. The disadvantage of Savonius rotors is their low efficiency compared with lift based devices; hence, many have dismissed their use and they are not widely used in the tidal stream or wind industries. Darrieus turbines are a common type of vertical axis design. They are characterised by aerofoil shaped blades and they rely on generating lift to make them rotate around a central axis. The disadvantages of Darrieus rotors are their very low starting torque and the large torque oscillations that they produce while operating. Darrieus turbines have been used in wind and marine energy applications. Gorlov turbines are another member of the vertical axis family. Like the Darrieus it uses aerofoil shaped blades and is lift based. The turbine has several desirable characteristics: it is self-starting and, as with all vertical axis turbines, due to its axial symmetry it will rotate in the same direction regardless of whether the tidal current is in flood or ebb (an important advantage when compared to axial flow turbines which are difficult to operate in a bi-directional fashion).

3. **Cross-flow Turbines:** These are turbines where the rotational axis of the rotor is parallel to the water surface and perpendicular to the incoming flow. Like the vertical axis turbines, they can employ either lift or drag type blades. Many cross-flow designs are drag based making them less efficient than other lift based turbine designs.

4. **Oscillating Hydrofoil:** The operating principle of these devices resembles that of the tail fin of a fish. The pitch of the foils is changed and depending on whether there is a positive or negative angle of attack relative to the tidal stream in flow, the hydrofoil will rise and fall in an oscillating motion. The foils drive hydraulic cylinders which pump hydraulic fluid that turns a hydraulic pump and in turn an electrical generator. Several tidal stream devices have been developed using this principle; however, none have ever made it beyond the prototype stage.

As well as the different concepts for extracting energy from the flow, tidal stream devices can also be distinguished by the way in which they are deployed. Devices can be fixed to the bottom or floating, fully submerged or surface piercing and there are an array of different foundation and mooring types. Floating devices will normally be tethered to the bottom using mooring lines; whereas, fixed devices can be installed using several different methods such as gravity foundations and piles.

2.3 Industry Leading Technologies

The landscape of leading tidal stream technologies has changed significantly since the 2010 report. For example, Atlantis Resources Corporation have moved away from their twin rotor concept and have also acquired MCT (Marine Current Turbines). There has also been progress from turbine developers concentrating on technology with a lower power rating, in recognition of the high risk and high capital costs associated with larger turbines. As a result, a number of the leading developers are producing full scale turbines with a rating significantly lower than 1MW. In many cases, technology developers with lower rated turbines – of the 100's kW scale – tend to target the 'community' scale market opportunities, such as remote islands and coastal communities, rather than the 'utility' scale applications that were the prime focus in 2010.

An overview of some of the current leading tidal stream devices is given in this section.

<table>
<tr><th>Tech Developer / Device</th><th>Turbine Type</th><th>Deployment Method</th></tr>
<tr><td>Atlantis Resources / AR1500</td><td>Three Bladed Axial Flow</td><td>Bottom mounted, gravity base</td></tr>
<tr><td colspan="3">The Atlantis resources AR1500 is the company’s latest three bladed axial flow turbine. The turbine is the result of several years of design and evolution which began with the AR1000, also a three bladed axial flow rotor. The AR1000 turbine was deployed at the European Marine Energy Centre (EMEC) in 2011 and featured an 18 m rotor diameter. The AR1500 was designed in conjunction with the Lockheed Martin corporation and builds on the AR1000 - it is Atlantis Resources’ most advanced turbine to date. The turbine has a power rating of 1.5MW at 3 m/s and features collective blade pitch control and yaw capability. The total mass of the unit is 1,500 tonnes in air (including the gravity foundation) and the company claim a 25 year design life. An AR1500 has been deployed and is currently operating at MeyGen in the Pentland Firth. MeyGen is a commercially operating tidal stream turbine array consisting of four turbines in total, one of which is an AR1500.</td></tr>
<tr><td colspan="3">

Figure 2, Atlantis' AR1500 prior to deployment at the MeyGen site

</td></tr>
</table>

Tech Developer / Device	Turbine Type	Deployment Method
Atlantis Resources / Seagen S and Seagen U	Two Bladed Axial Flow	Bottom mounted Pin Pile. The device is surface piercing

The Seagen S is turbine that was originally developed by Marine Current Turbines (MCT) and was acquired by Atlantis Resources in 2015. The device features twin 1 MW rotors each of which are mounted on a crossbeam which in turn is supported by a surface piercing tubular steel tower. Each rotor is designed for a rated flow speed of 2.5 m/s and has collective blade pitch control. The blades can be fully rotated allowing for bi-direction operation without needing to yaw the rotors. A 1.2MW version of the Seagen S turbine was deployed at Strangford Loch, Northern Ireland in 2008 and operated successfully for several years. The turbine has now been shut down and is set to be decommissioned by the end of 2017.

Design of the Seagen U turbine was originally started by MCT which, at the time, was a subsidiary of Siemens Plc. The turbine has a 20 m rotor diameter and a power rating of 1.5 MW. It is unclear how developed this turbine design is, as no prototype has actually been built or deployed to date. The turbine is designed to have a 20 year lifetime

Figure 3, MCT's 1.2MW Seagen turbine in Strangford Loch

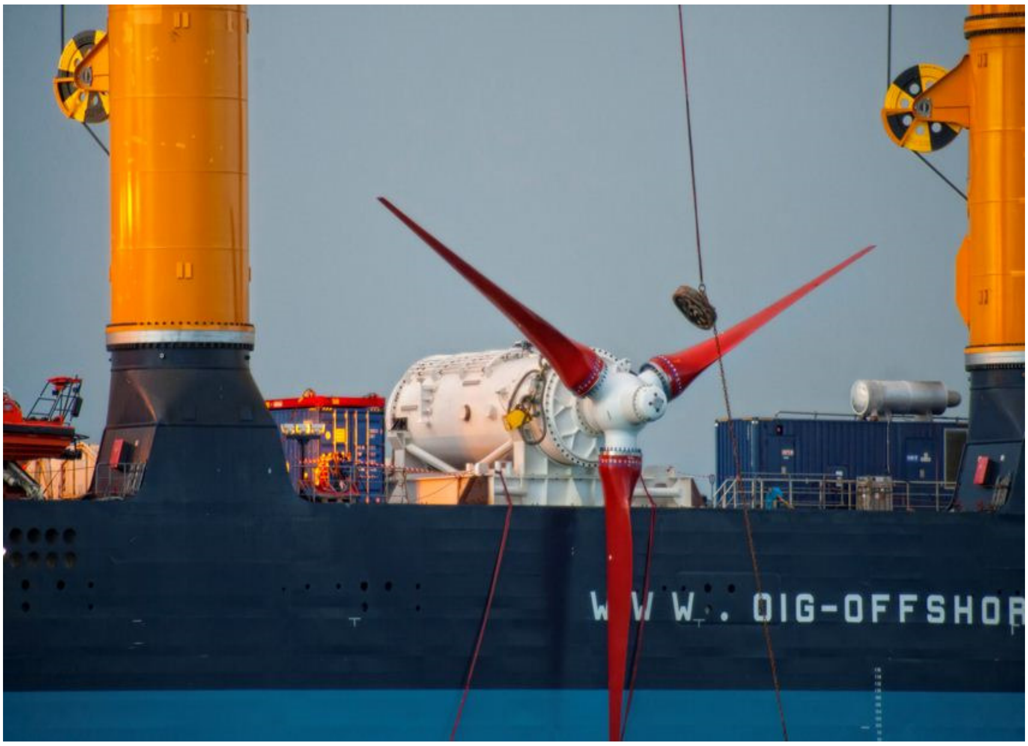
<table>
<tr><th>Tech Developer / Device</th><th>Turbine Type</th><th>Deployment Method</th></tr>
<tr><td>Andritz Hydro Hammerfest / HS1000 Mk1</td><td>Three Bladed Axial Flow</td><td>Bottom mounted gravity based (can be adapted for deployment with pins or piles depending on site conditions)</td></tr>
<tr><td colspan="3">Andritz Hydro Hammerfest is part of the Andriz Hydro GmbH group, a supplier of equipment and services to the hydropower industry. Andritz Hydro Hammerfest has previously deployed a smaller scale device (HS300) in Norway in 2004. The Andritz Hydro Hammerfest HS1000 Mk1 has been developed over several years and is the latest iteration of the company's three bladed axial flow turbine. Andritz previously deployed the 1MW HS1000 at EMEC in 2011. Three of Andritz's latest turbine model (AH1000 Mk1) have been deployed and are currently operating at MeyGen. The AH1000 Mk1 has a rated power of 1.5 MW and company claims a 25 year lifetime.</td></tr>
<tr><td colspan="3">

Figure 4, Andritz's HS1000 turbine prior to deployment at EMEC</td></tr>
</table>

Tech Developer / Device	Turbine Type	Deployment Method
Nova Innovation / Nova Innovation M100	Two Bladed Axial Flow	Bottom mounted gravity based
The Nova M100 is a 100kW two bladed axial flow turbine with a 9.5 m rotor diameter and a total mass of the unit in air of about 140 tonnes (including foundation). To date Nova have installed three M100 turbines in Bluemull Sound, Shetland. The first was deployed in March 2016, a second was installed in August 2016 and a third in February 2017. A further two will be added, bringing the total capacity of the project to 500kW. This project is the world's first community owned tidal energy project.		

Figure 5, Nova's M100 prior to deployment at Bluemull Sound, Shetland

Tech Developer / Device	Turbine Type	Deployment Method
Scotrenewables	Floating two-bladed axial flow	Bottom mounted gravity based

At 2MW the SR2000 is the largest floating tidal turbine in the world. Developed by Scotrenewables, it features 2 x 1MW turbines and is being tested at the European Marine Energy Centre (EMEC) in Orkney. Floating systems argue lower installation, operations and maintenance costs due to cheaper, more available vessels need for certain activities.

The SR2000 Mk 2 machine has received funding through the EU's Horizon2020 programme and is due to be tested under the FloTEC project in 2018.

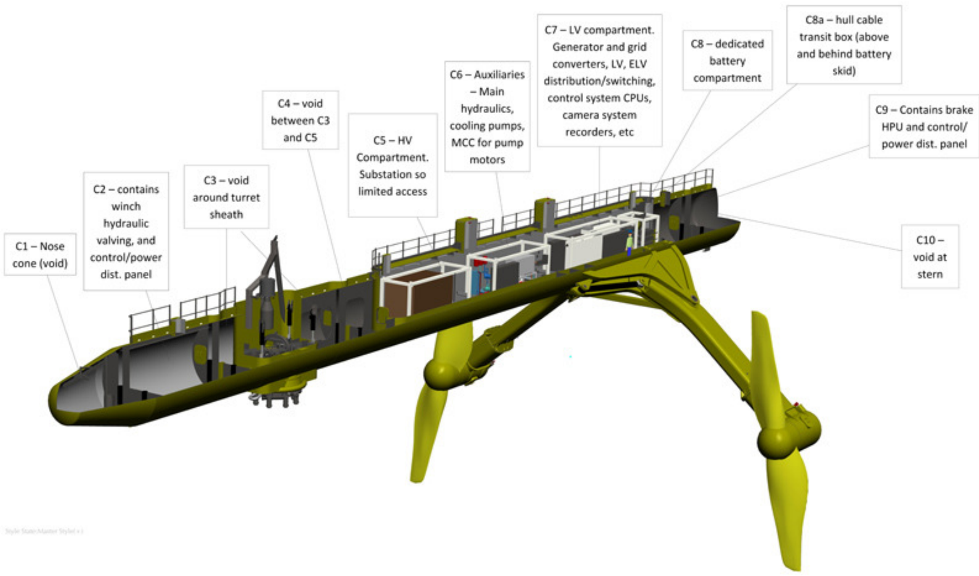


Figure 6, Scotrenewables 2MW SR2000 at EMEC (top) and a cutaway image (bottom)

Tech Developer / Device	Turbine Type	Deployment Method
OpenHydro / Open Centre Turbine 2 MW	Ducted Axial Flow Turbine	Bottom mounted gravity based

The OpenHydro turbine is a ducted, open centre turbine that uses a novel rim generator. The generator consists of multiple permenant magnets located around the outer rim of the rotor, and multiple coils located around the inner periphery of the duct housing (stator). The open centre of the turbine reduces the drag and the weight associated with a central shaft, allowing for a larger diameter turbine for the same mass. It is intended to also allow fish and marine mammals to swim through. The device is 16 m in diameter and is rated at 2 MW. The turbine weighs approximately 300 tonnes and is predominantly a steel assembly. The weight of the subsea base varies according to the characteristics of each site, but it is generally around 700 tonnes. Mounted on the subsea base, the top of the turbine sits 20 – 25 meters above the seabed.

OpenHydro were the first company to install a prototype turbine at EMEC in 2006. OpenHydro's project with EdF at Paimpol-Bréhat in Northern Brittany has two turbines deployed, the first of which was deployed in January 2016, with the second following in May 2016. In November 2016, the company installed its latest 2 MW turbine at the Cape Sharpe tidal site in Nova Scotia, Canada. The turbine is connected to the Canadian grid.

Figure 7, OpenHydro's turbine prior to deployment in Brittany, France

Tech Developer / Device	Turbine Type	Deployment Method
Tocardo / T2 Turbine	Two Bladed Axial Flow. Fixed pitch stall regulated.	Designed to be mounted on a semi submersible floating platform or a fixed structure

Tocardo have developed a compact 250 kW turbine designed to be deployed on either a fixed structure or floating platform. The philosophy is that the system is scalable and multiple machines can be deployed on a single platform. The turbine has two fixed pitch blades that can be fully rotated allowing for bidirectional operation. It operates in variable speed mode and is stall regulated. The turbine has a direct drive transmission incorporating a permanent magnet generator.

In February 2016 Tocardo agreed to demonstrate a 20-year pre-commercial array at the EMEC test site. The company has plans to install 8 T2 turbines at the site on a floating structure, named the Universal Foundation System.

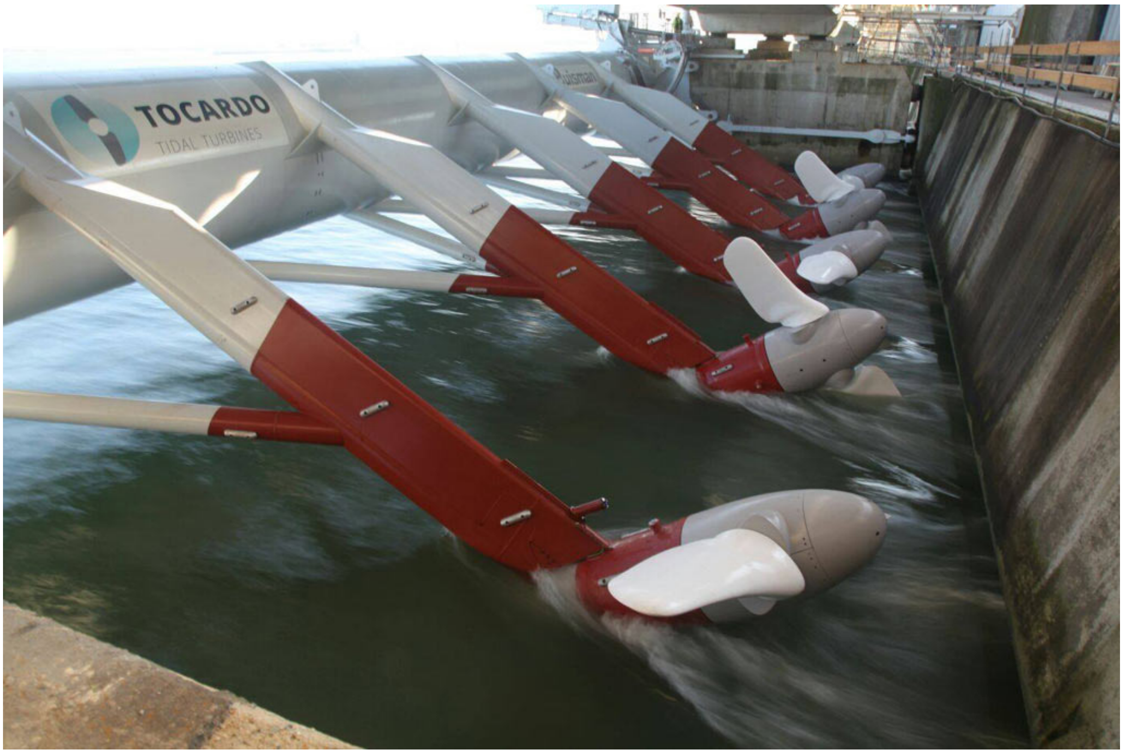


Figure 8, Five 250kW Tocardo T2s installed in the Oosterschelde, Netherlands

Tech Developer / Device	Turbine Type	Deployment Method
Schottel / SIT	Axial Flow, three-bladed turbine	Various – both fixed and floating configurations

The Schottel Instream Turbine (SIT) is a relatively small axial flow turbine with a 3 – 5m rotor diameter and rated outputs of between 54 - 70kW. It has been tested in a number of locations across the world, on a number of different platform types such as those developed by companies like Sustainable Marine Energy (SME) and Bluewater. Schottel's turbines can be installed on either fixed or floating structures and either as an individual turbine on a structure or multiple turbines per structure

Schottel are developing the TRITON seabed tethered, floating platform that can support up to 40 SITs. This platform is especially suited to deep water resources and comprises two spar buoys with turbine mounting structure, two mooring arms that are tethered to a universal joint within a seabed foundation. This arrangement allows the entire structure to yaw with the flow and enables the turbines to be lifted to the sea's surface to facilitate in-situ maintenance activities.

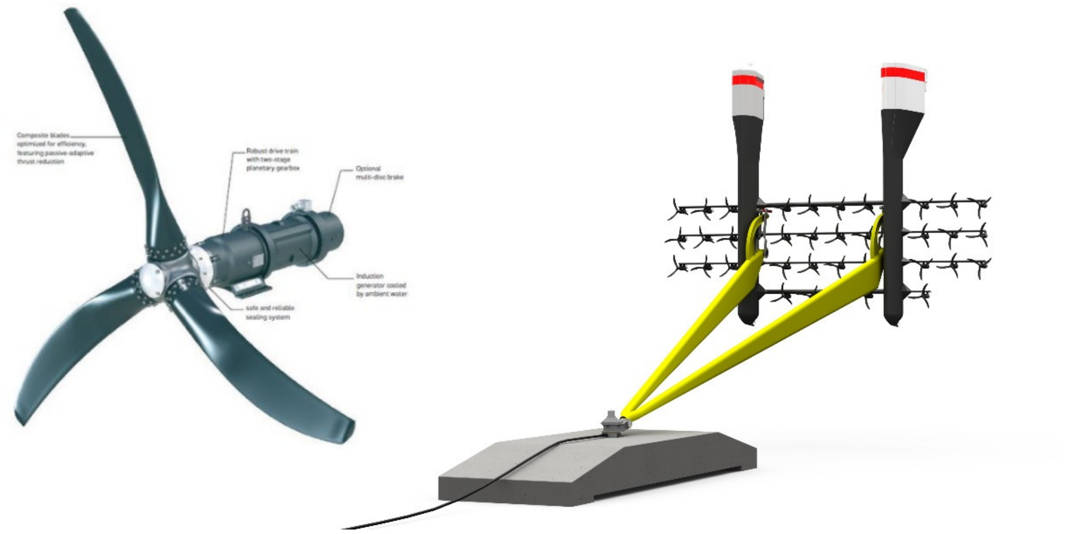
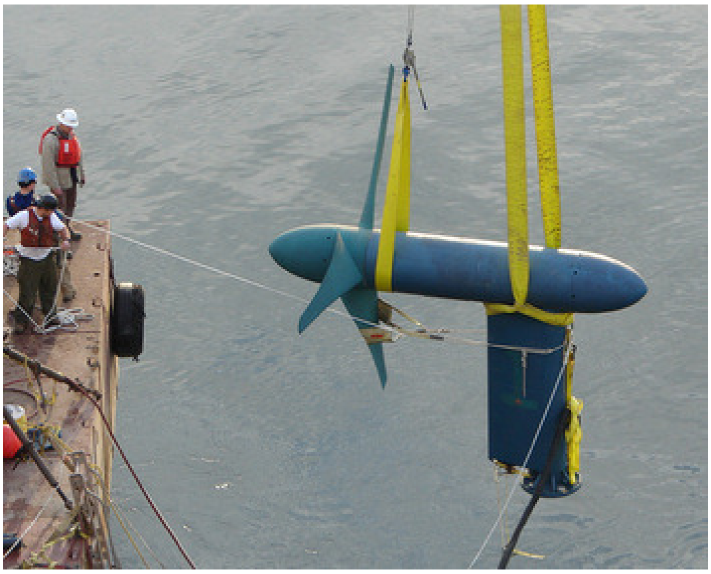


Figure 9, Schottel's 50kW SIT turbine (left), Schottel turbines on a Triton platform (right)

<table>
<tr><th>Tech Developer / Device</th><th>Turbine Type</th><th>Deployment Method</th></tr>
<tr><td>Verdant Power: Gen 5 Turbine</td><td>Three Bladed Axial Flow</td><td>Bottom Mounted. Gravity Based Tri-Frame</td></tr>
<tr><td colspan="3">The Gen 5 turbine is a 35 kW machine designed by American device developer Verdant Power. The turbine has fixed pitch blades and it is believed that it is stall regulated. The rotor diameter is approximately 5 m. The turbine also has the ability to yaw, enabling it to capture the flow in both directions. Verdant plans to deploy up to thirty Gen 5 turbines as part of the Roosevelt Island Tidal Energy project located in New York City’s East River. Verdant has already tested early generations of the turbine in this location. The company is also currently developing a Tri -Frame which will enable them to deploy up to three turbines on a single gravity based foundation.</td></tr>
<tr><td colspan="3">
Figure 10, Verdant's Gen 5 turbine during installation in New York</td></tr>
</table>

2.4 Test Sites and Projects

2.4.1 The MeyGen Project

The MeyGen project is located off the North coast of Scotland, south of the island of Stroma in the Pentland Firth. The project started operating in November 2016, and is currently the largest operational commercial tidal array in the world. The consented site covers an area of 3.5 square kilometres. The first stage of the project (called Phase 1A) consists of four turbines, each rated at 1.5 MW, which have all been installed and are operational. Three turbines have been supplied by Andritz Hammerfest Strom and one turbine has been supplied by Atlantis Resources. Phase 1B will add additional 6MW with four more turbines, Phase 1C (scheduled to commence installation 2019) will add a further 73MW of capacity.

MeyGen’s lease permits up to 398MW at the site, however, the grid capacity available is currently constrained to 252MW. Phase 2 and Phase 3 of the MeyGen project plan to build out past the currently planned 86MW from Phase 1.

2.4.2 EMEC Test Site

The European Marine Energy Centre was established in 2003 in the Orkney islands of Scotland. Since then it has been a hub for the development and testing of tidal stream devices. EMEC is also open to wave energy developers and several wave energy converters have also been tested here over the years. The grid connected tidal test site consists of test berths with water depths ranging from 12 m to 50 m. Each berth has its own 11 kV cable connection to the onshore substation.

As well as the grid connected test site, EMEC also offers real-sea test sites in the less challenging conditions of Scapa Flow and Shapinsay Sound. These sites provide a more flexible sea space helping close the gap between tank testing and marine deployments; acting as a stepping stone towards larger scale projects. Such accessible real sea testing enables marine energy developers and suppliers to learn lessons more cheaply, reducing the need for big vessels or large plant.

To date, around £36 million of public funding has been invested in EMEC by the Scottish Government, Highlands and Islands Enterprise, The Carbon Trust, UK Government, Scottish Enterprise, the European Union and Orkney Islands Council.

2.4.3 The Fundy Ocean Research Center for Energy (FORCE)

FORCE is a research centre situated in the Bay of Fundy Canada; an area that is home to some of the best tidal resource in the world. FORCE provides electrical infrastructure to project and technology developers in the tidal industry. Currently FORCE is supporting the following projects:

- A DP Energy and Atlantis Resources joint project, which has been awarded a 4.5MW feed-in-tariff by the Nova Scotia government.
- Cape Sharpe Tidal (CTS) – a joint venture between OpenHydro, DCNS and Emera. CTS installed its first grid-connected 2MW demonstration turbine in 2016 and plans its second installation in 2017, with another 2MW, 16 metre OpenHydro device.
- Black Rock Tidal Power, owned by Schottel Hydro plan to install the Triton s40 which will support 40 SITs.
- Minas Tidal, a Tocardo led project to deploy 5 x 250KW T2 Tocardo turbines on a semi-submersible platform
- Haligonia Tidal Energy Ltd, a DP Energy Affliate, will install 4.5MW consisting of 3 Andritz Hydro Hammerfest Turbines.

FORCE has been funded by a mixture of public (75%) and private (25%) funding and has cost approximately $45m CAD.

2.4.4 Perpetuus Tidal Energy Centre (PTEC)

The Perpetuus Tidal Energy Centre (PTEC) is a proposed tidal energy demonstration facility on the Isle of Wight with a planned electrical generation capacity of 30MW. The centre will be suitable for the deployment of up to full-scale single units and small arrays of tidal devices from prototype to pre-commercial demonstrators. The centre comprises an onshore site with substation/control room building and a development site for the deployment of devices, with the two sites being connected by a subsea cable corridor along which the power cables pass. The PTEC development site is an area of approximately 5 km^2 located off the southern tip of the Isle of Wight in England.

The PTEC facility will provide tenants with grid connection infrastructure via subsea export cables as well as navigation aids to allow developers to utilise the area to demonstrate their tidal technology. Tenants will provide the tidal energy devices and foundation/support structure.

2.4.5 Morlais Tidal Energy Demonstration Zone

The Morlais Project (the West Anglesey Demonstration Zone) is a 150MW marine energy demonstration zone located to the west of Holy Island in Anglesey, Wales which will allow up to 12 developers to install and demonstrate their devices. The West Anglesey Demonstration Zone is an area especially chosen by the Crown Estate as being a suitable location for the exploitation of tidal energy.

The site is less than 1 km from the coast at the nearest point and offers 35 square kilometres of total seabed area, average depth of 40m and accelerated flows of up to 3.1 m/s. The project comprises an onshore site with a substation building and an offshore development site for the deployment of devices, with the two sites being connected by a subsea cable corridor along which up to 30 power cables will be routed. Morlais will be providing consent and onshore connection to the National Grid infrastructure.

2.4.6 Shetland Tidal Array

The Shetland tidal array located in Bluemull Sound Scotland has been developed by Edinburgh based device developer Nova Innovation. The project is a collaborative partnership with Belgian renewable energy leader ELSA, who provided project management and operational input, as well as financial support. The project is being developed in two phases. The first, which was completed in the spring of 2017, consists of three 100 kW Nova M100 tidal stream turbines. It is believed that two more M100 turbines will be added as part of phase two of the project. The authors are not aware of the timeline for completion of phase two. Nova Innovation are also developing a project off the coast of Wales.

2.4.7 DP Energy Projects

In addition to their FORCE activities, DP Energy are developing three other tidal stream projects including the 30MW West Islay Tidal Energy Farm which has an Agreement for Lease from the Crown Estate. DP Energy's other two project are the Irish Fairhead project and development rights for a 200MW Orkney project.

2.4.8 Other Global Projects

There are number of other tidal stream projects in various stages of development across the globe. These include:

- Normandie Hydro project, a DCNS project with 14MW consented.
- Raz Blanchard, France, a potential 5.6MW installation
- OpenHydro Nagaski, Japan, a planned 2MW DCNS project
- A number of smaller demonstration projects in South East Asia and China

3 Economic Analysis

3.1 Basis of Technical Assumptions

3.1.1 Appropriate Project Characteristics

The tidal stream industry has changed over the last few years, since our previous report for the States of Jersey; there have been commercial and technological failures, improvements in understanding, the entry and exit of companies from different sectors, and drastic changes in the policy landscape. As a result, acknowledging the need for improvement and survival, the industry has gradually both technically and commercially begun to mature.

Project developers are no longer proposing unrealistic, utility scale projects that will be delivered as soon as possible, but are instead, now taking a more pragmatic and sensible view, proposing staged development and expansion of sites. This approach is demonstrated by the Industry's leading project which is being developed by MeyGen (See Section 2.4).

Similarly to MeyGen, other project developers are proposing phased and sensible roll out of their project sites; PTEC (30MW), Nova (2MW at Bardsey Sound, 3MW at Bluemull), DP Energy (Islay 30MW, Fairhead: 10MW then 90MW), SSE (30MW Brims), Minesto (1.5MW, then 7.5MW, then up to 80MW), Morlais (30MW). The industry is currently focusing its efforts on planning and developing projects of around 30MW. These are large enough to benefit from some economies of scale and be commercial ventures rather than demonstrations, but small enough to be readily financeable.

For these reasons, we have modelled a 30MW tidal stream project in Jersey, rather than the ~85MW project we had previously proposed in 2010, which was based on an aim of harnessing a certain percentage of the energy at the site. Our current assessment, does not preclude the expansion of the project to a larger installed capacity in future development phases but it does provide a realistic and achievable project scale that could be the first project in the island's waters.

3.1.2 Appropriate Technology Selection

A significant constraint affecting the choice of turbine technology for the selected tidal site is the available depth; ~23m at LAT. Turbines rotors need sufficient clearance between their blade tips and the water surface to avoid high loading from wave action and for vessel passage, and clearance between the blade tips and the seabed to avoid regions of slower flow speeds, see Figure 11. In this case, a turbine rotor would need to be sufficiently smaller than the available 23m minimum depth in order to avoid these adverse loading conditions. At present, none of the current state of the art tidal turbines are well suited to this constraint and so, would need to be adapted to suit the site's conditions – either rotor sizes made smaller or larger to improve commercial viability. A 15m region of the water column is likely to provide the most preferred flow conditions for a turbine's rotor.

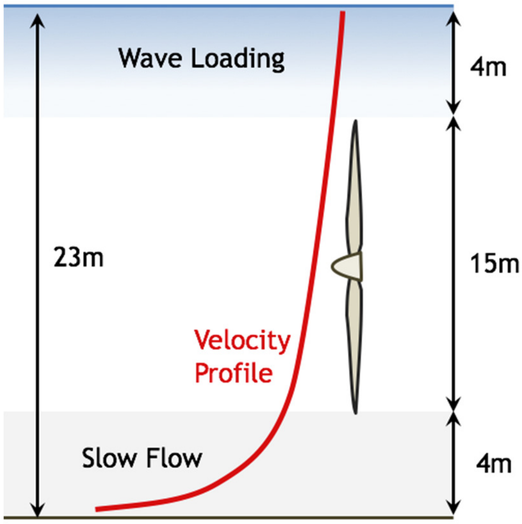


Figure 11, A turbine's rotor needs to fit within the physical constraints of the site, including; regions of high wave loading and slow flow close to the seabed

There are two main categories of tidal turbines; those that are fixed, bottom mounted to the seabed, and those that are floating, mounted on floating platforms. Examples of each of these are given in Section 2 and generic representations shown in Figure 12. Each have their own merits, challenges and associated costs. We have modelled generic cases for both the fixed bottom and floating turbine categories to approximate units with an effective rotor diameter of 15m – the largest rotor diameter that is practically feasible within the site's depth constraints. In reality, each unit may feature one rotor of 15m diameter, or multiple smaller rotors with an equivalent swept area of 15m diameter. We do not anticipate this to significantly affect the normalised capital cost per unit.

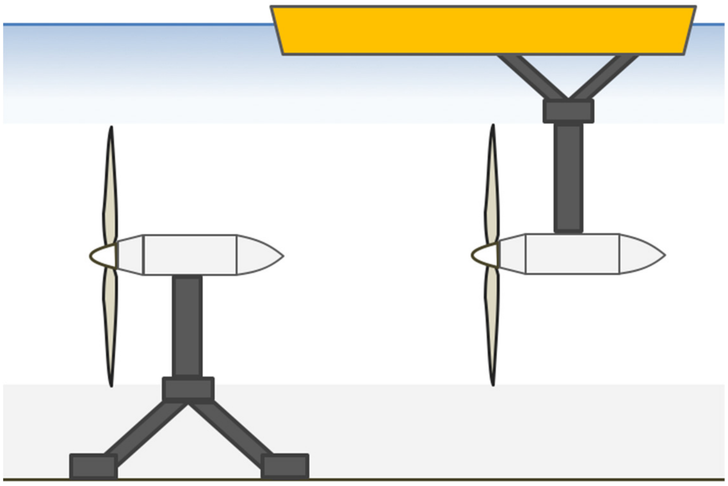


Figure 12, The two types of turbine categories considered in this study; A generic fixed, bottom mounted turbine (left) and a generic floating turbine mounted to a surface floating platform (right)

The majority of the commercial turbines currently being developed by the industry are rated for environments with higher flows than there are at the Jersey site. A balance needs to be struck between capital cost and the revenue potential of a turbine at a particular site. This balance is described by a proposed farm's capacity factor i.e. turbines rated for the highest flow speeds at the site will capture more energy but will be expensive and have a low capacity factor. The 2010 report showed that the most economical solution for the Jersey site would be to install turbines designed and rated for speeds of approximately 2m/s; this is a result that has been used for the economic modelling in this report.

3.1.3 Tidal Farm Area

The area of seabed taken up by the proposed 30 MW tidal farm will vary depending on whether fixed bottom or floating technology is used and on the number of turbines mounted on each fixed bottom or floating structure. An estimation of the area taken up with the two technologies is provided in Table II. Different scenarios are presented based on the number of turbines per structure. The total seabed area enclosed by a tidal farm is likely to be higher than the figures estimated here as devices will need to be located to make use of the best areas of resource and where the bathymetry and seabed slope are suitable.

Table I, Tidal farm seabed area estimation for various numbers of turbines per structure.

Technology type	No. of turbines per structure	Footprint of a 30MW farm (km²)
Fixed bottom structures	1	1
	2	0.5
	3	0.3
Floating structures	1	3.7
	2	1.9
	5	0.7
	7	0.5

3.2 Resource

The resource assessment presented in the 2010 report has been used in this analysis. The 2010 assessment was based on Admiralty chart data, tidal elevation data for 2006, and an ADCP transect survey from the site. A velocity shear profile due to seabed friction was included in the 2010 assessment. The difference between the modelled surface flow speed in the Ruau Channel and the flow speed estimation within the water column is shown in Figure 13. The rotor will be installed such that its hub height (centre of the rotor) will be at around 11 m depth to allow a similar clearance above and below the rotor. This will result in a rotor hub height flow speed of approximately 91% of the surface flow speed. This factor has been applied to the modelled flow speed data to represent the free stream tidal velocity at the rotor hub which is used to calculate the turbine power output.

	Approximate Width Across Channel (m)																					
Depth (m)		250	500	750	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000	4250	4500	4750	5000	
0	0.0	90.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	90.6	0.0
1	0.0	89.6	99.1	99.2	99.3	99.4	99.7	99.4	99.7	99.7	99.1	99.2	99.6	99.4	99.2	99.7	99.5	99.5	99.7	99.3	89.8	0.0
2	0.0	88.6	98.2	98.3	98.5	98.8	99.1	98.8	99.1	99.1	98.5	98.5	99.0	98.7	98.6	99.1	98.9	98.9	99.1	98.5	89.0	0.0
3	0.0	87.5	97.3	97.4	97.7	98.2	98.5	98.2	98.4	98.4	97.8	97.8	98.3	98.0	97.9	98.5	98.3	98.3	98.4	97.7	88.1	0.0
4	0.0	86.3	96.2	96.5	96.9	97.5	97.9	97.5	97.7	97.7	97.1	97.1	97.7	97.3	97.3	97.9	97.7	97.7	97.7	96.9	87.2	0.0
5	0.0	85.0	95.1	95.5	96.0	96.9	97.3	96.9	97.0	97.0	96.3	96.4	97.0	96.6	96.5	97.2	97.1	97.1	97.0	96.0	86.2	0.0
6	0.0	83.6	94.0	94.4	95.0	96.2	96.7	96.2	96.3	96.3	95.5	95.6	96.2	95.8	95.8	96.5	96.5	96.5	96.3	95.0	85.1	0.0
7	0.0	82.0	92.7	93.2	94.0	95.4	96.0	95.4	95.5	95.5	94.7	94.8	95.4	94.9	95.0	95.8	95.8	95.8	95.5	94.0	84.0	0.0
8	0.0	80.2	91.3	91.9	93.0	94.6	95.3	94.6	94.7	94.7	93.8	93.9	94.6	94.1	94.2	95.1	95.1	95.1	94.7	93.0	82.7	0.0
9	0.0	78.2	89.8	90.6	91.8	93.8	94.6	93.8	93.8	93.8	92.9	93.0	93.7	93.2	93.3	94.3	94.4	94.4	93.8	91.8	81.3	0.0
10	0.0	75.7	88.1	89.1	90.6	93.0	93.8	93.0	92.9	92.9	91.9	92.0	92.8	92.2	92.4	93.5	93.6	93.6	92.9	90.6	79.8	0.0
11	0.0	72.7	86.2	87.4	89.2	92.1	93.0	92.1	91.9	91.9	90.9	91.0	91.8	91.1	91.5	92.6	92.8	92.8	91.9	89.2	78.1	0.0
12	0.0	68.6	84.0	85.5	87.7	91.1	92.1	91.1	90.8	90.8	89.8	89.8	90.8	90.0	90.4	91.7	91.9	91.9	90.8	87.7	76.0	0.0
13	0.0	62.1	81.3	83.3	86.1	90.0	91.2	90.0	89.7	89.7	88.6	88.6	89.7	88.8	89.3	90.8	91.0	91.0	89.7	86.1	73.7	0.0
14	0.0	0.0	78.1	80.7	84.2	88.9	90.3	88.9	88.5	88.5	87.2	87.3	88.5	87.5	88.1	89.7	90.1	90.1	88.5	84.2	70.7	0.0
15	0.0	0.0	73.7	77.4	82.0	87.7	89.3	87.7	87.2	87.2	85.8	85.8	87.1	86.0	86.8	88.6	89.1	89.1	87.2	82.0	66.7	0.0
16	0.0	0.0	66.7	73.1	79.5	86.4	88.1	86.4	85.7	85.7	84.2	84.2	85.7	84.4	85.3	87.4	88.0	88.0	85.7	79.5	60.4	0.0
17	0.0	0.0	0.0	66.2	76.3	85.0	87.0	85.0	84.1	84.1	82.3	82.4	84.1	82.5	83.7	86.1	86.8	86.8	84.1	76.3	0.0	0.0
18	0.0	0.0	0.0	0.0	72.0	83.4	85.7	83.4	82.3	82.3	80.2	80.3	82.2	80.4	81.9	84.7	85.5	85.5	82.3	72.0	0.0	0.0
19	0.0	0.0	0.0	0.0	65.2	81.6	84.2	81.6	80.2	80.2	77.7	77.7	80.1	77.9	79.8	83.1	84.0	84.0	80.2	65.2	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	79.5	82.6	79.5	77.7	77.7	74.6	74.6	77.6	74.8	77.3	81.3	82.5	82.5	77.7	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	77.0	80.8	77.0	74.5	74.5	70.4	70.4	74.5	70.5	74.2	79.2	80.7	80.7	74.5	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	73.9	78.8	73.9	70.3	70.3	63.7	63.8	70.3	63.9	70.0	76.7	78.6	78.6	70.3	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	69.7	76.3	69.7	63.7	63.7	0.0	0.0	63.7	0.0	63.4	73.6	76.1	76.1	63.7	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	63.1	73.2	63.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	69.5	73.1	73.1	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	69.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.9	68.9	68.9	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	62.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	62.4	62.4	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Figure 13 Estimated flow speed at a cross section of the Ruau Channel as a percentage of the modelled surface flow speed.

3.3 Annual Energy Production

The Annual Energy Production (AEP) has been estimated by modelling a horizontal axis turbine within the resource available in the Ruau Channel. Key parameters of the model ae given in Table II. A sensitivity analysis was carried out to determine the rated flow speed of the rotor which led to the lowest cost of energy. This resulted in using a rated flow speed of 1.9 m/s.

Table II Key parameters used in the AEP estimation model.

Model parameter	Unit	Value
Rotor diameter	m	15
Rotor power coefficient, C_P	-	0.45
Rotor rated flow speed	m/s	1.9
Rotor cut in flow speed	m/s	0.7
Turbine efficiency (mechanical and electrical)	-	92%
Turbine rated power (Net)	kW	258
Electrical transmission efficiency (mean)	-	98%
Total capacity of tidal farm	MW	30
Total number of turbine units	-	107
Total number fixed bottom or floating structures (depends on how many turbines are mounted on each structure)	-	Approx. 15 to 107

The hourly estimated flow speed for 2006 has been used to estimate the AEP. It has been assumed that the turbines are suitably spaced such that full wake recovery occurs. This spacing is included in the tidal farm seabed area estimates in Table I. The net AEP for the 30 MW tidal farm has been estimated at 36.4 GWh/year.

3.4 Cost Modelling

Capital costs, operation and maintenance (O&M) costs, and decommissioning costs have been estimated for the tidal stream farms proposed. The costs are based on industry estimates, component cost estimates, and comparable costs from the offshore wind industry. High level cost estimates of a tidal stream farm in the Ruau channel are shown in Table III. A pessimistic, base, and optimistic case have each been estimated to provide an indicative range of potential project costs. The pessimistic and optimistic cases are calculated by increasing or decreasing all costs (capital, O&M, and decommissioning) by 20% respectively. The range in costs across the three scenarios is represented in Table III. The costs in Table III are based on the Ruau Channel project being installed after 130 MW of tidal stream technology has been installed across the European sector – i.e. once there is greater learning and maturity within the tidal stream industry. The 130MW of capacity is equivalent to Phase 1 of the MeyGen project being installed and at least one other major tidal farm before the Jersey site is developed. If the Ruau Channel project is installed later in the industry's development (i.e. when the total installed capacity (TIC) of tidal stream is greater than 130 MW) then the project costs will reduce due to industry learning.

Table III, Cost estimate for a 30 MW tidal farm in the Ruau Channel, installed after the TIC of tidal stream technology has reached 130 MW.

Item		Cost (£ million)
Capital cost	Design, consents, surveys, and project management	7 - 12
	Offshore and onshore electrical infrastructure and grid connection	21 - 32
	Turbine support structure	15 - 30
	Turbines	30 - 45
	Capital cost total	*74 - 120*
O&M cost / year		2.7 – 6.7
Decommissioning cost		3.7 – 6.0

The cost of energy has been estimated using a discounted cashflow analysis with a 25 year operational lifetime. The capital cost has been assumed to be spread over two years, with 25% of the capital cost in the first year and 75% in the second year. Income from energy production has been assumed to start in the third year. The cost of decommissioning has been included as a sinking fund with equal payments in the 6th to 15th years inclusive, with the full fund value maturing in the final year of operation. An annual interest rate of 0.3% has been applied to the balance in the sinking fund. The years in which the sinking fund is payed into and the interest rate are representative of the low risk form of security likely to be required by governments[4].

3.5 Future Cost Estimation

In 2016, ITPEnergised estimated the TIC of tidal stream technologies up to 2020 by analysing all proposed tidal stream projects and their likely timelines. This is shown in Figure 14 and provides an indication of the timescale within which tidal stream technology costs are likely to reduce.

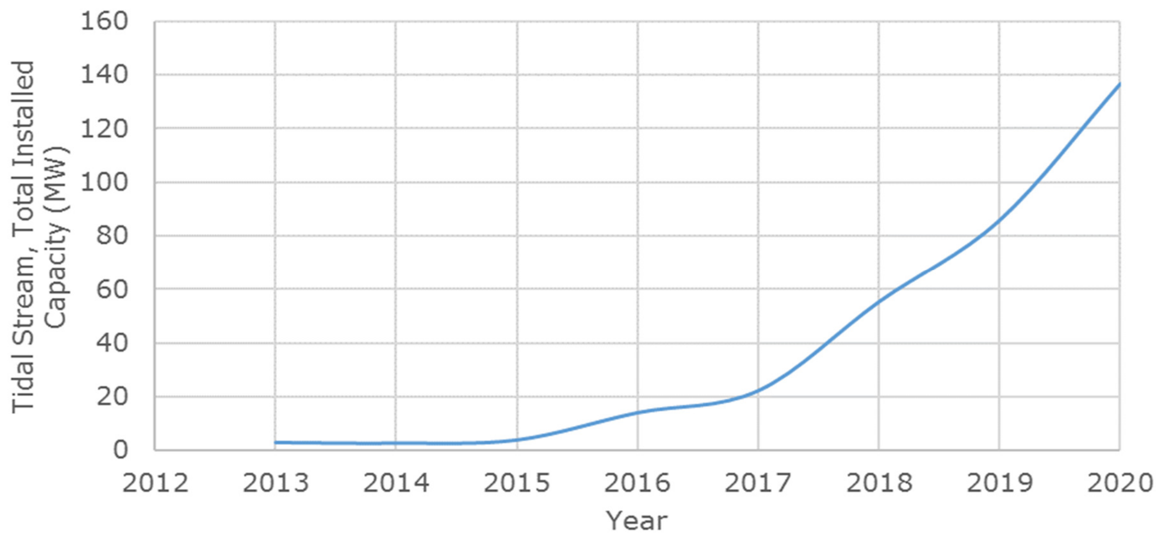


Figure 14 Estimate of global Total Installed Capacity of tidal stream technologies (ITPEnergised)

[4] DECC, Decommissioning of offshore renewable energy installations under the Energy Act 2004, 2011

Due to the young nature of the tidal stream industry, costs are expected to reduce significantly following large scale deployment of tidal turbine arrays. To include this affect in the analysis a learning rate has been applied to the costs using the equation and recommendations given in the EU's SI Ocean's Ocean Energy: Cost of Energy report[5]. The learning rate for offshore wind capital costs has been estimated at 15% by ITPEnergised. This same learning rate has been applied to all capital, O&M, and decommissioning costs in this analysis.

A pre-tax discount rate of 12.9% was suggested by the Department for Business, Energy & Industrial Strategy (BEIS) in 2014 for tidal stream technologies[6]. The same report also suggested a pre-tax discount rate of 8.9% for offshore wind in 2014. In the analysis the discount rate has been estimated by applying a linear reduction from 12.9% applicable at the TIC of tidal stream technologies in 2014 to 8.9% for a TIC of tidal stream technologies equivalent to that of offshore wind in 2014. The pre-tax discount rate used is shown in Figure 15.

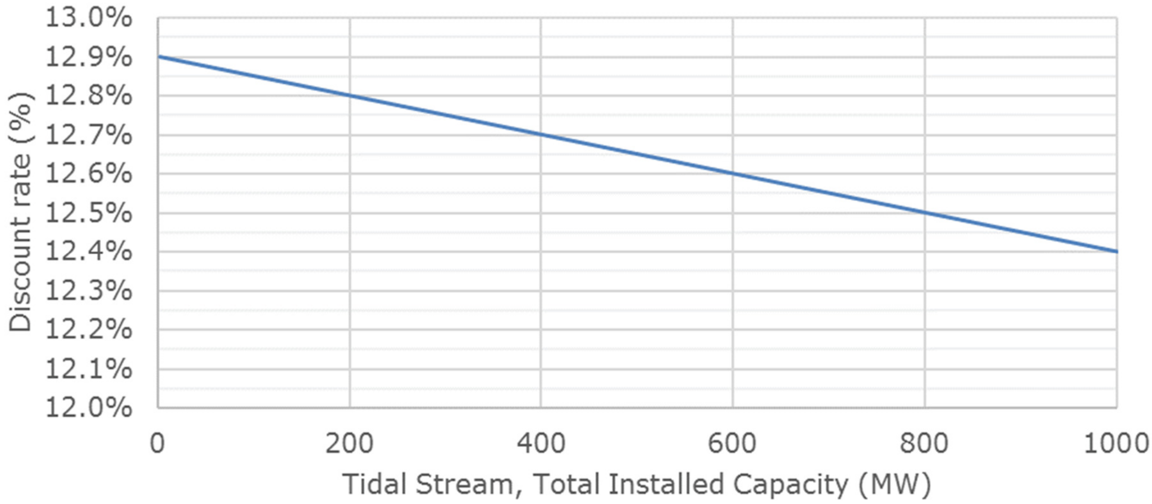


Figure 15 Pre-tax discount rate applied to tidal stream technology.

3.6 Cost of Energy

The estimated cost of energy at the Ruau Channel for the pessimistic, base, and optimistic scenarios are given in Figure 16 and Figure 17 for floating and fixed bottom tidal arrays respectively. Key values are shown in Table IV. All figures are shown in 2017 prices. The reduction in the cost of energy as the TIC of tidal stream technologies increases is due to cost reductions as a result of learning and to a lesser extent due to the reducing discount rate with increasing TIC that has been applied.

The cost of energy estimates included in the 2010 report are also shown on Figure 16 and Figure 17 for comparison. These have been adjusted by the UK RPI index[7]. The main difference between the 2010 and 2017 estimates are significantly higher capital costs, these have arisen from the tidal stream industry developing and understanding project capital costs to a greater degree.

[5] SI Ocean, Ocean Energy: Cost of Energy and Cost Reduction Opportunities, May 2013

[6] BEIS, Electricity Generation Costs, November 2016

[7] Office for National Statistics, RPI all data, CHAW index, 2017

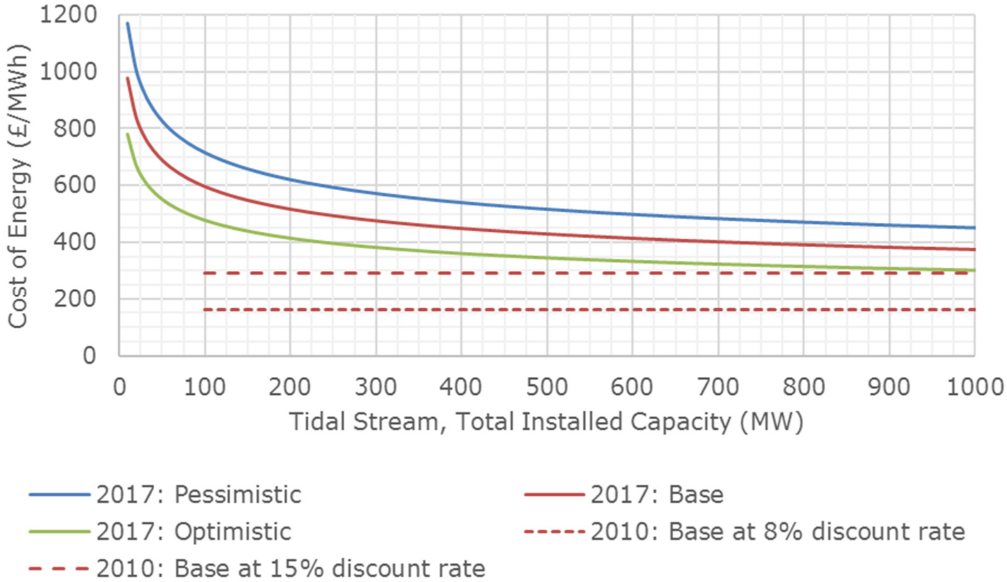


Figure 16 Estimated cost of energy for a floating device for the Ruau Channel based on the Total Installed Capacity of tidal stream technologies at the start of the Jersey project.

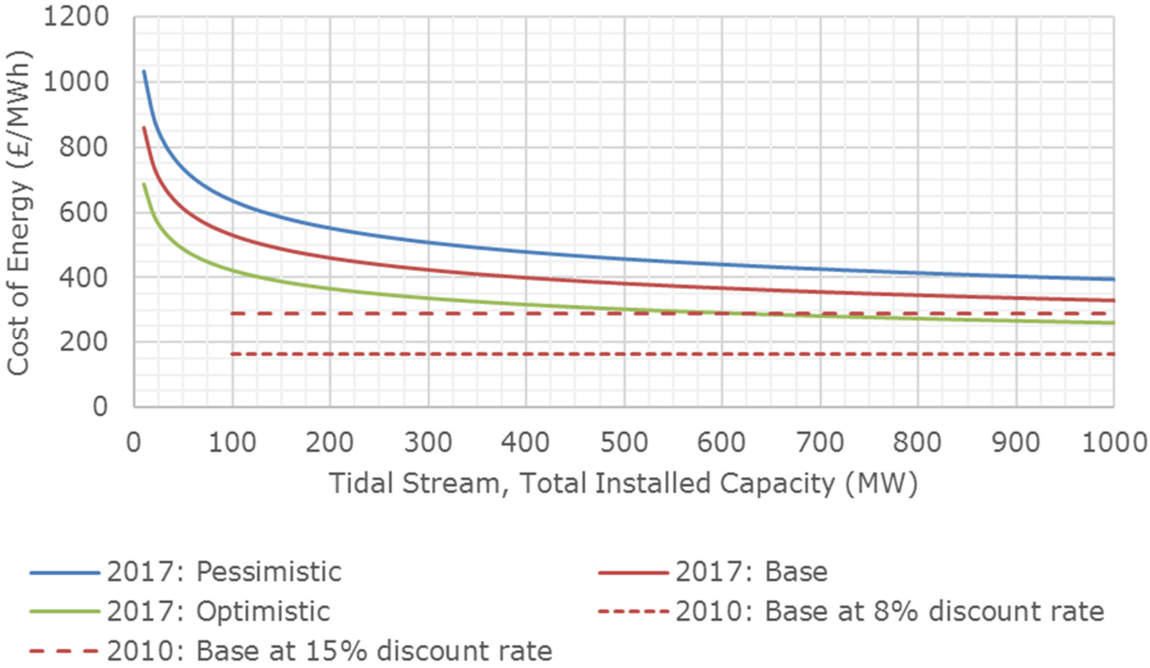


Figure 17 Estimated cost of energy for a fixed bottom device for the Ruau Channel based on the Total Installed Capacity of tidal stream technologies at the start of the Jersey project.

Table IV Key values of the estimated cost of energy for the Ruau Channel based on the Total Installed Capacity of tidal stream technologies at the start of the Jersey project.

	Cost of energy					
Tidal stream TIC	**Floating device**			**Fixed bottom device**		
	Pessimistic	**Base**	**Optimistic**	**Pessimistic**	**Base**	**Optimistic**
MW	**£/MWh**	**£/MWh**	**£/MWh**	**£/MWh**	**£/MWh**	**£/MWh**
10	1,170	980	780	1,030	860	690
20	1,010	840	670	890	740	590
50	830	690	550	730	610	490
100	720	600	480	640	530	420
140 (year 2020 planned TIC)	670	560	450	590	490	400
200	620	520	410	550	460	370
500	520	430	340	460	380	300
1000	450	380	300	390	330	260

4 Tidal Stream Support & Policy Review

Putting aside the wider political turmoil, the past 12 months have been a turbulent time for UK energy policy and many changes have had significant implications for the marine energy sector.

In 2016 the UK Government restructured its departments; this included the abolition of the Department for Energy and Climate Change (DECC), as it was absorbed into BIS under the new name of the department for Business, Energy and Industrial Strategy (BEIS). BEIS has overall responsibility for energy policy in the UK although, through acts of devolution, Scotland, Wales and Northern Ireland now all have more responsibility for energy.

Marine licensing is an area where Scotland and Wales have gained more control over marine activities in their coastal waters. Marine Scotland and Natural Resources Wales now have jurisdiction over the licensing of offshore energy projects of less than 100MW.

The Crown Estate's devolution led to the establishment of the Crown Estate Scotland which, as part of its remit, took over responsibility for leasing the Scottish seabed on 1st April 2017.

Scotland has around a third of the UK's tidal stream energy resources and two thirds of the UK's wave resources. The Scottish Government acknowledges this fact and has continued to be supportive of the marine energy sector through capital funding initiatives and streamlining the consenting and planning processes.

4.1 Revenue Support

4.1.1 Renewables Obligation

To date, the only revenue support being given to tidal stream technologies in the UK is through the UK's previous Renewables Obligation scheme, which provides Renewable Obligation Certificates (ROCs) per unit of generated electricity in addition to the sale price of the generated electricity. Tidal projects receive 5 ROCs per MWh of electricity. The current, average value[8] of a ROC is £48.39, whereas the typical wholesale market price of electricity is currently[9] around £42/MWh – meaning that the projects supported by the ROCs scheme receive the equivalent price of around £284 per MWh supplied to the grid.

The Renewables Obligation scheme closed to all new capacity (except solar PV and onshore wind, which closed early) from 1 April 2017, though a number of projects have been given 'grace periods' to either 31st March 2018 or 30th September 2018. These grace periods allow the operator of some generating stations to apply for accreditation on or after 1 April 2017, if they meet certain, predetermined conditions. For example, Scottish offshore wind demonstration or floating wind projects have a grace period as long as they have preliminary accreditation by 31 March 2017 and to credibly demonstrate they could be commissioned by October 2018.

4.1.2 Contracts for Difference

The UK Government replaced the RO scheme under the wider Electricity Market Reform in 2012 and now provides revenue support to low-carbon energy technologies through the Contracts for Difference (CfD) programme. The first CfD auction round was preceded by an interim scheme known

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[8] http://www.epowerauctions.co.uk/eroclatest.htm

[9] http://www.energybrokers.co.uk/electricity/historic-price-data-graph.htm

as Final Investment Decision enabling for Renewables (FIDeR) which provided CfD contracts at a pre-determined strike price to some projects that were close to FID. In this case, successful bids from offshore wind projects, for example, were awarded CfDs with an administratively set value of £150/MWh. The first CfD auction round less than 12 months later, however, provided offshore wind with bids as low as £114.39/MWh, suggesting the FIDeR contracts were overpriced and did not offer good value for the UK energy consumer – a view supported by the NAO[10].

The second round of CfD auctions, with an annual budget of £290m, opened in April 2017 with pre-qualifications followed by bids during early summer. This round was only open to "Pot 2" technologies (offshore wind, geothermal, anaerobic digestion, biomass, tidal & wave) and, unlike the first auction round, did not have a second component for Pot 1 technologies (Energy from waste, hydro, landfill gas, onshore wind, solar PV). BEIS announced this second round in November 2016 and offered Strike Prices of £310/MWh for wave and £300/MWh for tidal stream for projects due to deploy in 2021/22. Critically, however, BEIS had excluded one essential detail from the auction's wording; the first CfD auction had offered 100MW of ring-fenced capacity for wave and tidal stream technologies, meaning that bidding projects would receive the stated strike price – this however was excluded from round 2. The implication of this was that, whilst specific strike prices were stated, wave and tidal projects would need to directly compete on price with the other technologies in pot 2. The second round auction winners saw two wind farms bid for a strike price of £57.5 MWh[11] – far lower than any wave or tidal project could hope to bid. This effectively left the marine energy and floating offshore wind sectors without access to a revenue support mechanism.

Tidal stream, wave and floating offshore wind technologies are not yet fully commercialised products and the different types of designs within each technology category are at various stages of TRL (Technology Readiness Level) development (see Figure 18). Many tidal stream technologies, for example, are currently stranded in TRLs 7-9 and do not have a suitable mechanism to support them in the development pathway from CRL 2 (Commercial Readiness Level) to a commercial, bankable product. This has had a noticeable effect on some projects with the Isle of Wight's 30MW PTEC project being a good example – this project is now on hold until a route to market becomes available. Other technology developers are actively looking at overseas markets with more supportive polices such as France and Canada, or to markets with high electricity prices such as off-grid islands in South East Asia.

[10] https://www.nao.org.uk/wp-content/uploads/2014/06/Early-contracts-for-renewable-electricity1.pdf

[11] Contracts for Difference Second round allocation, www.gov.uk

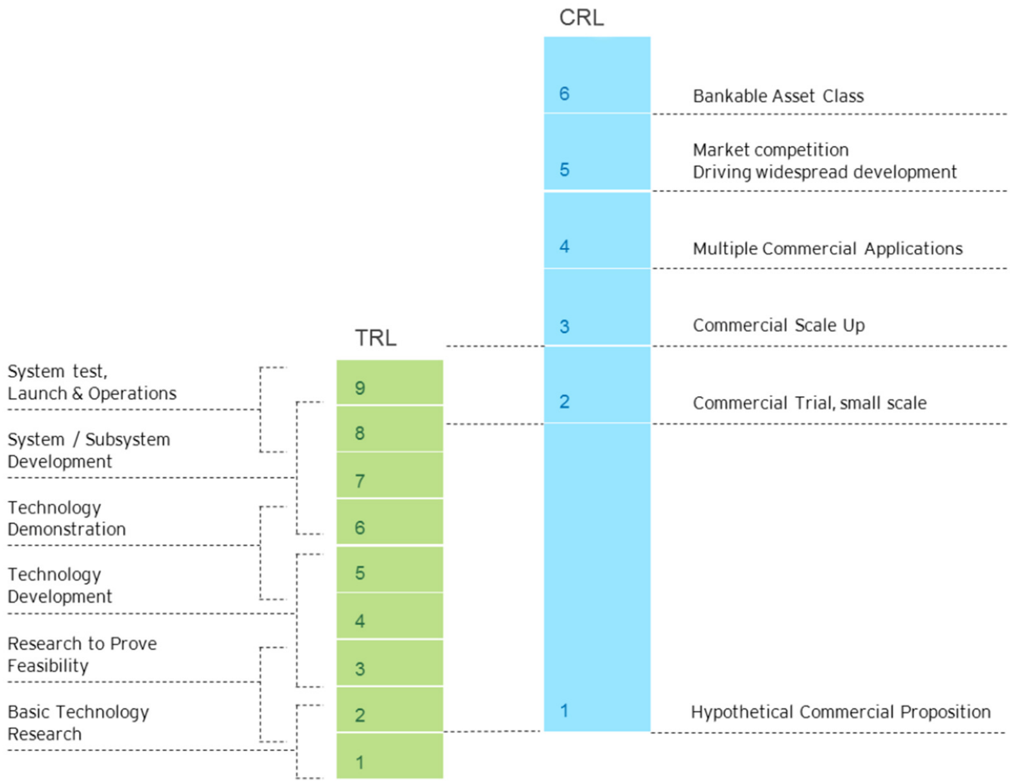

Figure 18 Technology and Commercial Readiness Levels [Source: ARENA[12]]

The industry is currently proposing a new mechanism, separate from the larger scale CfD programme, that will provide support for pre, or near, commercial technologies such as tidal stream turbines and floating offshore wind. The proposed mechanism is based on the US Production Tax Credit model and is being presented as an "Innovation PPA" where technologies will compete for support via sales of electricity from companies wanting to support innovation. In this mechanism, buyers of tidal stream energy, for example, would pay to receive electricity at above market rates but, in turn, receive tax credits per kWh at government-set rates and ceilings. These tax credits would subsequently reduce an organisation's corporation tax, thereby offsetting the additional cost of buying electricity at a higher price. This new mechanism would not impact consumer bills (a key driver for UK energy policy) or require long-term budget commitment from BEIS.

4.2 Capital Funding

Tidal stream developers Atlantis and Tocardo have both recently raised decent amounts of private debt to fund their on-going activities – clearly signalling a maturing sector. That said, marine energy technologies have been heavily reliant on UK and European R&D grant funds to support development from concept to sea-going deployments. MeyGen, the world's most advanced tidal stream project, for example, received around £23m of Scottish public sector investments in addition to debt from DECC and the Crown Estate.

In 2012, the Scottish Government established the Renewable Energy Investment Fund (REIF), with a budget of £103m. Part of REIF's aim is to help marine projects become commercially viable and has so far invested over £40 million in a range of innovative wave and tidal schemes.

[12] ARENA (2013) Self-assessment tool for the accelerated step change initiative: the Commercial Readiness Index

Further support was provided by the Scottish Government which established Wave Energy Scotland (WES) in 2014 with a budget of around £10m per year. This programme is taking an innovative, staged approach to the development of wave technology through its research and funding calls.

The European Union has been another essential funder for tidal technologies and grants have been made available under a series of R&D programmes including; FP7, Horizon 2020, Ocean ERA-NET co-fund, FORESEA and the European Regional Development Fund. Wales, for example, is heavily benefitting from EU ERDF money and the Welsh European Funding Office (WEFO) is administering funds from the ERDF for a number of tidal energy projects around Wales.

The UK Government's main R&D funding body is Innovate UK (formerly the Technology Strategy Board) and is an executive non-departmental body sponsored by BEIS. Innovate UK has provided grants for a range of marine energy projects at different stages of development, from early stage feasibility to large scale deployments. Its primary funding stream is the Energy Catalyst programme.

Projects financed by the R&D grant funds are supported by the UK's world leading marine energy research and testing facilities such as EMEC, Narec, WaveHub, FaBTest and the testing tanks at University of Edinburgh and Plymouth University. Many UK Universities are also supported by EPSRC to conduct fundamental research into marine energy.

4.3 Ocean Energy Race

The Ocean Energy Race[13] is a campaign devised by the ocean energy sector and being co-ordinated by the industry's trade association, RenewableUK. Its aim is to present the arguments and evidence to support the wave and tidal sectors and ask the UK Government to include them in its Industrial Strategy. This political campaign has a number of key messages that are focused on attracting the attention of politicians deciding the UK's future energy policies. Some of these points include;

- Britain as a maritime nation leads the world in the development of wave and tidal energy technologies.
- Marine energy is a modern UK success story and a natural growth area for Britain – testing and developing world-leading technology, attracting investment and exporting overseas.
- British companies often constitute more than 80% of the supply chain for marine energy projects and nearly £450m has already been invested in the UK supply chain
- This sector has vast export opportunities for UK companies and by 2050, this global market could grow to £76bn

As previously mentioned, the primary 'ask' from the Ocean Energy Race campaign is to provide revenue support for wave and tidal energy through an Innovation PPA scheme.

[13] http://www.renewableuk.com/page/WaveTidalEnergy

5 Conclusions

5.1.1 The State of the Industry

There are a number of well-developed tidal turbines that have been outlined in this report. Although the industry's progress has not been as quick as was predicted in 2010, there are a proven tidal stream technologies that are suitable for extracting tidal stream energy. The leading technologies are mainly axial flow turbines and are either fixed to the seabed or float in the water column or at the sea surface. Leading examples of these can be seen from developers Atlantis Resources, Andritz Hydro and Scotrenewables. Recently, the industry has also seen developments in smaller scale turbines from technology developer Schottel, Tocardo and Nova Innovation. These smaller turbines offer smaller magnitudes of risk and capital costs.

Building on this technology development, the industry has started to move on from testing commercial demonstrators to developing its first multi-turbine tidal stream farms, with MeyGen being the prime example of a farm development. Notwithstanding this progress, reliability issues and high capital costs are still a feature of the industry, highlighting that the industry is still in its infancy.

Globally, Canada, France and to a lesser extent East Asia are developing tidal stream technologies and projects; there are a number of planned multi-megawatt farms in France, and the FORCE project in Canada has the leading technology and project development companies active in harnessing one of the best global resources in the Bay of Fundy.

5.1.2 Jersey's Resource

There is a significant resource of tidal stream energy off the coast of Jersey. As reported in 2010, 360GWh of tidal stream energy passes through the North-East site annually. The flow speeds at the site may not be one of the top 10 sites when compared to other sites in the UK, however, there is a resource that may be commercially of interest in the future. The environmental considerations, risks to development and need for further environmental planning as outline in the 2010 report still stand.

5.1.3 Revenue Support in the UK

Removal of the Renewable Obligation Certificates and a move towards Energy Market Reform where tidal stream turbines are expected to compete with technologies like offshore wind has been a blow to the industry in the UK. The industry is currently lobbying for better financial support mechanisms to assist with UK developments and taking technologies through to commercial maturity.

5.1.4 Cost of Energy Predictions

It is estimated that to harness this resource, a 30MW farm of fixed bed turbines would have a levelised cost of energy £490 per MWh, based on a discount rate of approximately 12%, and an industry total installed capacity of 140MW (this is the TIC planned for 2020). In 2010, the IT Power report predicted a more optimistic value of £238 per MWh, adjusted for inflation and using a 15% discount rate. The difference in these predictions is explained by higher capital costs the technology developers are seeing now compared to what was expected in 2010. The industry is now more developed and there is far more confidence in today's costs as they are based upon the deployment experiences over the past 7 years.

It is predicted that in the future, once the industry has made significant progress in project developments (i.e. TIC > 1GW), a tidal farm at Jersey's Ruau site would have a cost of energy between £260/MWh and £390/MWh.

5.1.5 Development of a Tidal Stream Project in Jersey

Considering the high cost of energy predicted here, it is unlikely that project developers would look to exploit Jersey's tidal streams in the near future without incentives in the way of either revenue support, capital cost support or a streamlined development process and political desire put in place by the States of Jersey. Considering the significant energy resource, the site may become commercially viable as the industry progresses, however, from these predictions it seems unlikely that a tidal stream development would be able to compete in terms of cost of energy with other offshore renewables including offshore wind and potentially tidal lagoons.

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